Modelling of domestic refrigerators' energy consumption under real life conditions in Europe

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Background

Domestic refrigerators are one of the largest energy users in private homes in developed countries and, as such, have become a target for energy efficiency improvements. An approach for improvements was the implementation of the European Energy Label in mid-nineties. On the one hand, its goal is to prompt new technical developments on the part of the manufacturers by intensifying competitive situation. On the other hand, the Energy Label intends to inform consumers about the efficiency of appliances allowing them to make a better-informed purchase decision. Currently, refrigerators' Energy Label test in Europe is carried out at an ambient temperature of 25 °C without door openings. During the test, the fresh food compartment is empty. These test conditions are different from the conditions in most households which is accordingly a frequent point of criticism.

Aims

The main objective of the study was the investigation and assessment of refrigerators' energy consumption under realistic working conditions by laboratory tests with special focus on covering the entire consumer relevant area. The factors ambient temperature, daytime temperature variations, internal compartment temperature setting, load, heat load by warm food and door openings were of particular interest.

Material and Methods

Consumer real life behaviour in using domestic refrigerators was studied by an online survey (n=1011) and by in-home studies (n=100) in four European countries (Fig.1). The data obtained served as a basis for designing and implementation of laboratory experiments. Key information gathered from the experiments was used as a base for the development and validation of a simplified model that allows predicting the energy consumption of refrigerators in use.

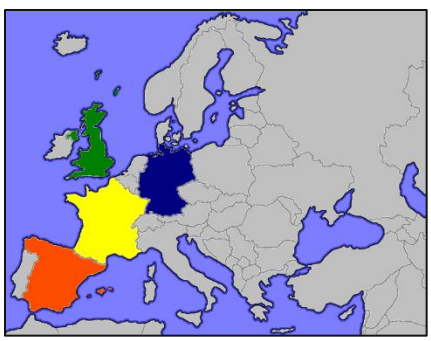

Fig. 1: Coverage of online survey and in-home studies (illustration modified based on digitale-europakarte.de)

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Reference: www.bsh-group.de

Results

The results of both consumer studies show that consumer behaviour in handling domestic refrigerators varies over a wide range (Tab. 1). Besides differences in national habits, also differences within the countries were apparent suggesting that consumer behaviour is individual and dependent on innumerable factors.

		D	E	F	GB
Ambient temp. (°C)	min	0-3	0-3	0-3	0-3
	max	40-43	>44	40-43	>44
	average	16-19	20-23	16-19	16-19
Compartment temp. (°C)	min	0	0	0	1
	max	10	12	12	10
	average	5,8	5,2	4,5	3,9
Heat load by warm food (kJ), 95. percentile	min	355	730	601	642
	max	495	979	866	723
	average	368	730	650	653
Door openings per day (estimated)	min	0-5	0-5	0-5	0-5
	max	>40	>40	>40	>40
	average	11-15	11-15	11-15	11-15

Tab. 1: Main findings of the consumer studies

Laboratory experiments revealed that the ambient temperature has the greatest impact on a refrigerator's energy consumption (Fig. 2), followed by the compartment temperature and heat load caused by warm items. The refrigerators' load under static conditions as well as the number of door openings have almost no impact on energy consumption.

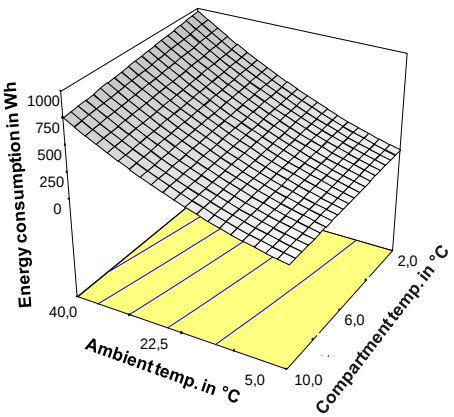

Fig. 2: Influence of ambient and compartment temperature on refrigerators' energy consumption, 3D surface

The applied modelling method follows a first-principle approach adjusted by experimental data. When compared to laboratory results, model predictions show a reasonable agreement for the whole range of investigated conditions. The model predicts almost all values within a ±10 % deviation band.

Conclusion

By linking consumer behaviour as well as actual conditions and energy consumption tests in laboratory, the present study revealed that refrigerators' energy consumption is highly variable and sensitive to consumer behaviour and conditions in private homes.

The developed model can be used complementary to the Energy Label in consumer counselling and education and at the point of sale to predict actual energy consumption under the respective relevant conditions.